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ABSTRACT

A description is provided of a demonstration use of the ATS-3 satellite to provide computer-assisted instruction to students at an Indian Pueblo in New Mexico from the computer center at Stanford University's Institute for Mathematical Studies in the Social Sciences. The role of this and other technologies in improving productivity and efficiency in education are also discussed. (Author/RH)

Using Satellites to Improve Efficiency in Delivery of Educational Services*

by

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Abstract

This paper describes in some detail a demonstration use of the ATS-3 satellite to provide computer-assisted instruction to students at an Indian Pueblo in New Mexico from the computer center at Stanford University's Institute for Mathematical Studies in the Social Sciences. The verbal presentation will discuss the role of this and other technologies in improving productivity and efficiency in education.

Introduction

In recent years advances in communication and education have made possible two very attractive classes of educational technology. The first of these is the development of broadcast technology by which radio or television programs originating at a single point can be distributed to, potentially, many millions of educational users. The second and much more recent of these advances centers around potential use of a computing system to provide interactive instruction. By tailoring curriculum to an individual's needs and providing immediate and accurate feedback, instruction via computer offers great potential, perhaps greater than the broadcast media.

Computer-assisted instruction (CAI) is an increasingly familiar technology at academic research institutions and in the journals. Problems of cost and availability have, however, stalled efforts at implementation on any substantial scale. For this reason, in our work on CAI development at Stanford University's IMSSS, we have paid increasing attention to the basic economic trade-offs involved and to the problems of implementation facing a school administration that want to utilize CAI.

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Provision of CAI or CMI (computer managed instruction) of any sophistication implies the need for one or a few large central computing facilities -- at least with presently available technology. Thus if rural regions or dispersed populations are to be able to share in the potential of interactive educational technologies, an extensive communication system is required. In a previous paper -- Jamison, Suppes, and Butler [1970] -- we examined the basic economics of providing CAI in urban areas. Since all student terminals can, under urban conditions, be located reasonably close to the central computation facility, cost and implementation problems are reduced. In this present paper we examine the somewhat more difficult problem of providing CAI to dispersed populations.

Our work in developing cost models for distribution of CAI to dispersed populations has been part of a project funded by the Bureau of Education for the Handicapped, U.S. Office of Education, to develop CAI materials for deaf students. The deaf constitute a rather highly dispersed population within the United States and problems of communication to support a CAI system for them are paradigmatic for dispersed populations of other types. Other dispersed populations include American Indians, Americans whose first language is Spanish, medical doctors, students at isolated rural schools, and migrant workers (who have the additional communication difficulty of being mobile.)

Experience has indicated that cost and complexity of terrestrial communication systems for CAI are often a stumbling block. Establishing and servicing circuits in romote areas is difficult. Independent telephone companies do not always provide data services or equipment. There are areas in the United States which cannot be reached by this type of CAI service due to lack of telephone company facilities. It could be argued that because it is more difficult to supply dispersed populations with CAI than to supply more concentrated populations, the dispersed populations should be left until last. Our view is that, at the very least, we should examine with care the costs of different technologies that could provide CAI service to dispersed populations (including satellite communication), and on the basis of these costs let the decision makers responsible for providing education to these groups make decisions about how their resources should be allocated.

In this paper we describe a demonstration designed to provide working experience with distributing CAI to dispersed populations by satellite. In the oral presentation we will discuss the implications of satellites and other technologies for improving productivity and efficiency in education.

Project Description

The existence of communication channels via orbiting satellites represents a tremendous technological advance over terrestrial telephone circuits. Military, commercial and scientific interests have already profited from this technology. It seems reasonable to propose that education should also participate in technological advances, and perhaps even pioneer some in the years to come. The establishment, operation and extension of a satellite communication link for education would provide a basis for educators to explore new technologies and for communication scientists to apply their technology to CAI.

Some of the inherent problems in using satellite channels for large-scale CAI distribution will require years for solution. In particular, bandwidth allocation and low cost ground station development are significant problems to be solved. Multiplexing techniques capable of handling, perhaps, hundreds of up-link channels to a satellite must also be developed.

In May of 1970, IMSSS demonstrated the operational practicality of a satellite communication link by operating 10 terminals in a local school via NASA's ATS-1 satellite for two short periods. As a result of this test, proposals for a full-scale experiment were prepared for early 1971 start-up. By May of 1971 IMSSS had secured satellite time on NASA's ATS-3. Equipment deliveries, site selection, licensing, and installation problems occupied the staff until November of 1971. The equipment shown in Figure 1 and defined in Table 1 was installed at Stanford and at Isleta Pueblo Elementary School near Alburquerque, New Mexico.

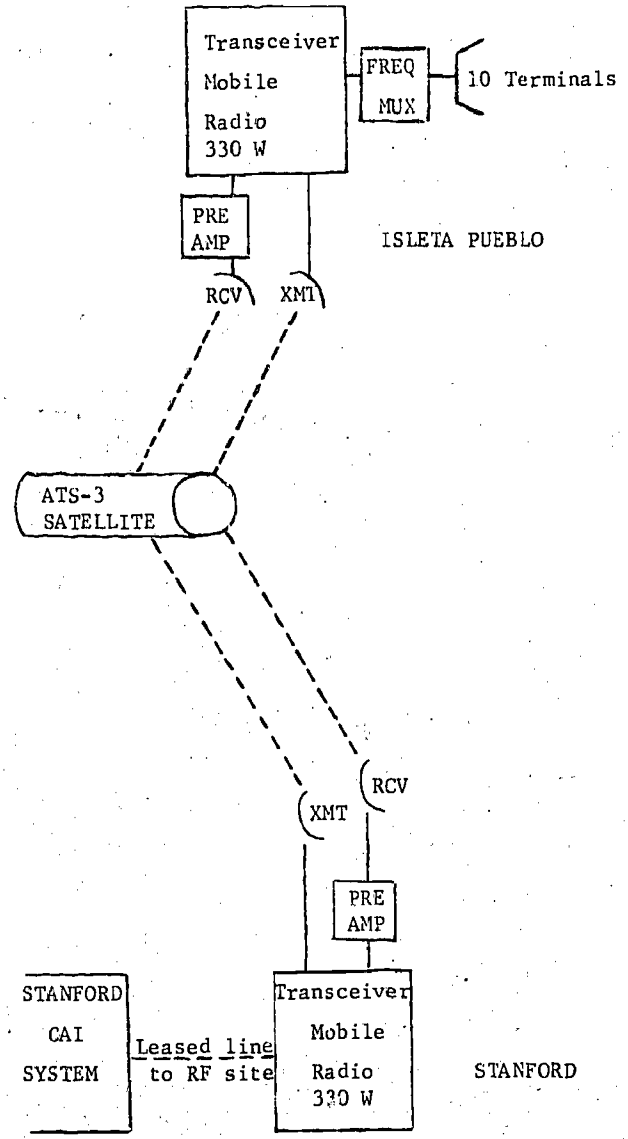

Figure 1: ATS-3 Satellite Communication System

After the testing began, various problems occurred and it was evident that at least three mistakes had been made in planning the experiment. First and foremost, the technology involved was insufficiently understood, making it very difficult to bring an unfunded project to operational status without adequate engineering support. Second, permission had been granted to use the Isleta Pueblo School in return for the educational benefits of CAI. IMSSS had promised to start in July of 1971, and there was still no CAI available by November. Third, it was a mistake to attempt to operate an exciting educational venture for only 90 minutes per day (our assigned ATS-3 time). The internal demand for usage at the school was high for such arbitrary time limitations.

The only way to resolve the educational commitment we had made to Isleta Pueblo was to install a telephone circuit which would provide the CAI service while work continued on the satellite circuit for 90 minutes each day. This solved the educational problem successfully. However, the RF circuit remained only marginally useful. As debugging progressed, the need for either increased power or more sophisticated data encoding became more and more apparent.

The circuit that was established on the ATS-3 has proved both interesting and challenging. ATS-3 is a low-power satellite operating in the 2-meter band from 136 to 150 MHz. At these frequencies, high gain antennas are quite large and impractical. Available ground equipment is good, but not quite good enough to overcome the power limitation within our environmental and data requirements.

Conventional frequency multiplex equipment used on phone line circuits and operating within the 500-3000 Hz band was used for data encoding. The voice band signal was sent from IMSSS to an antenna site on a hill behind the main Stanford campus. There, a standard mobile radio transceiver and Yagi antenna was used to communicate with Isleta via ATS-3. At Isleta similar RF and frequency multiplex equipment was installed in the schoolroom. The antennas were placed on the building's roof. The objective was to successfully transmit frequency multiplexed data tones over this link. Eight data channels were placed on the circuit. Each data circuit's transmit tone was set at -9dBm for a composite signal of OdBm. All circuits were full duplex so the send and receive circuits were identical and separate. Minimum signal to noise ratio for reliable operations of the frequency multiplex circuits is about 7db. Therefore a minimum signal to noise ratio of 16db seemed to suffice for the satellite circuit.

Equipment selected for this experiment is shown in Table 1. The transceiver has a final output of 330 watts. The cable is low-loss, the pre-amp is a low noise design with less than a 4db noise figure. The antennas are Yagi arrays with a gain of 13.6db.

Table 1

Equipment for IMSSS ATS-3 Project

Pre-amplifier	-- Vanguard Dual-gate MOSFET
Antennas	-- Cush-Craft A-144-20T
Multiplex	-- Collins Radio Corporation TMX-201
RF Cabling	-- Prodeline Foam-flex
Transponder	-- G,E MASTR Mobile Radio Base Station

Additional figure calculations were initially made as given in Tables 2 and 3, and later revised to the figures in Table 4. A noise figure of

Table 2

Uplink Calculations for IMSSS ATS-3 Project[a]

Link components	Power contribution
Transmitter power (250 watts)	24.0 dbw
Transmitter cable loss	-4.0 db
Transmitting antenna gain	13.6 db
Polarization loss	-3.0 db
Free space loss	-168.3 db
Receiving antenna gain	7.5 db
Receiver cable loss	-1.3 db
Carrier power at the receiver	-131.5 db
Noise power density (noise temperature = 900°)	-199.1 dbw/Hz
Carrier-to-noise power per unit band width	67.6 db/Hz

a. The uplink frequency is 149.22 MHz

Table 3

Downlink Calculations for IMSSS ATS-3 Project[a]

Link components	Power contribution
Effective radiation power	22.5 dbw
Back-off from satellite (half-power mode)	-5.0 db
Sharing of power between 2 channels	-3.0 db
Polarization loss	-3.0 db
Free space loss	-166.5 db
Receiving antenna gain	13.6 db
Carrier power at the receiver	-141.4 db
Noise power density (noise temperature = 800°)[b]	-199.5 dbw/Hz
Carrier to noise ratio per unit band width	58.1 db
Uplink noise contribution	-0.5 db
Band width (receiver-14kHz)	41.5 dbHz
Carrier to noise ratio	16.1 db
FM improvement[c]	25.5 db
Test tone to noise ratio (TTNR)	41.6 db

a. The downlink frequency is 135.6 MHz.

b. The noise temperature of 800° corresponds to a sky temperature of 500° and a pre-amplifier noise figure of 3db. This condition does not always exist.

c. There is a 4.5KHz deviation with 1 volt RMs; f_m = 1kHz.

Table 4

Modified Downlink Calculations for IMSSS ATS-3 Project[a]

Link components	Power contribution
Effective radiated power	17.0 dbw
Back-off from satellite (half-power mode)	-5.0 db
Sharing of power (4 channels)	-6.0 db
Polarization loss	-3.0 db
Free space loss	-166.5 db
Receiving antenna gain	13.6 db
Carrier power at receiver	-149.9 db
Noise power density	-199.5 dbw/Hz
Carrier to noise ratio	49.6 db/Hz
Uplink noise contribution	-0.5 db
Band width (receiver-14kHz)	41.5 dbHz
Carrier to noise ratio	7.6 db
FM improvement	25.5 db
Test tone to noise ratio	33.1 db

a. The downlink frequency is 135.6 MHz.

33.1db was indicated for the worst possible configuration, half-power operation of four channels. From experience it has been indicated that practical noise figures of 20db to 25db are the best obtainable.

However, noise figures measured by analog means are only a partial indication of circuit performance for data transmission. With a required noise figure of 16db and actual figures of 20db, the presence of both space and terrestrial noise sources becomes apparent. Any noise source which produces a few db loss in carrier power or transmits broad band RF in the vicinity of our antennas can cause a data error. If suitable error detection and correction schemes are used, low tolerance circuits can be made usable. Unfortunately, it was not possible to implement such schemes on this link. Errors are an important limiting factor for an IMSSS terminal. Student lesson periods are 6 to 10 minutes long at the elementary school level. One or two errors during the course of a lesson can confuse and possibly hinder a student's progress. Therefore, the ATS-3 circuit, in its present configuration, is definitely marginal for CAI use.

The earliest problems encountered in the satellite project were concerned with receiver desensitization. Several varieties of tuned stubs, improved cable harnesses, a few cavities and an active filter pre-amp design were tried. Antenna separation was also necessary. At Stanford even a metal building was interposed to reduce the coupling between send and receive arrays.

Another problem also arose with the antennas. The simple Yagi design is a low-cost, low-gain antenna. Circularity deviations of the structure were troublesome, especially at the threshold level of operation. We experienced polarization changes of 4db on most days. Coupled with a spin modulation of 2db to 4db from the satellite, we had a difficult time even talking over the circuit for quite awhile. We also found that there can be significant pattern anomalies in the Yagi design requiring tuning of their pointing angles rather than pointing them entirely by compass readings. The final antenna configuration has turned out to be two twin Yagis at Isleta, one quad Yagi for receive and a single helix for transmitting at Stanford. We felt that quad helix arrays everywhere would be optimal, but so far the necessary funds have not been available.

Our transmit power at 330 watts output with a 1db or 2db loss in the cable is sufficient to almost saturate the ATS-3 transponder. A power increase to 1 kilowatt would only increase our down link power by about 2db. We conclude that money would be better spent on antennas than on more RF power.

Comparisons with other ATS-3 sites show that we are doing fairly well. On January 11, 1972 we measured 29db (for simplex operation) while Alaska showed 14db and Mojave 34db. Alaska has a very quiet environment but a very bad antenna pointing angle. Mojave achieves its good signal with the help of a receiving dish antenna and a high power transmitter.

Reliable 20db noise figure operation was considered good enough for a test in spite of the known problems. On March 15, 1972, student lessons at Isleta were begun using the satellite link. By that time ATS-3 was in the equinox and our use was limited to 45 minutes each day. This use was continued for two weeks and did not prove successful. Error rates were high enough to prematurely terminate the sessions on most days.

Several interesting noise sources were noticed during this operation period. AC power line interference at Isleta had been seen before as random spikes on the base band signal. However, as the spring winds began at Isleta, a broad band RF interference signal developed. It was both wind and power line related. The noise bursts seemed to only start during winds of 20 mph or so. The noise source has not yet been located. Another wind related noise may be carried by sand particles hitting the receive antenna. This AC noise contribution was often sufficient to completely obscure our signal at Isleta.

While the Stanford site does not have wind or AC problems, there are other sources of noise. There is a spurious carrier on the ATS-3 which appears occasionally. It contributes noise by robbing us of power in the satellite. This spur is a defect in the satellite which cannot be controlled.

During March we also were affected by a signal source know as the "mysterious sweeper." An RF signal sweeps across our band about once a minute on most days. This signal must be generated some where close to Stanford. Perhaps it is some antenna test facility in the Palo Alto area. Our receive signals have a signal strength of about .1μvolt/meter. It does not take a very strong signal to affect our reception.

We believe that we have achieved the best level of operation possible with our satellite system. Improvements can only be made with additional funding. For a ground station cost of $3,200 and total project costs of less than $20,000 we have achieved a stable useful RF data link. It is subject to burst noise which reduces its utility for elementary level CAI usage.

IMSSS has accomplished many of its original goals for this experiment. We now have operating experience to install and maintain a satellite data link. We have the knowledge to make a link operate successfully. We will continue to explore opportunities for the development of satellite communication links for education.

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